What is wrong with current translocations? A review and a decision-making proposal

Irene Pérez[1,2*], José D Anadón[2,3,4], Mario Díaz[5], Graciela G Nicola[6], José L Tella[3], and Andrés Giménez[2]

Should a species be translocated? Uncertainty regarding the necessity and feasibility of many translocations complicates answering this question. Here, we review translocation projects, both published and unpublished. Our results indicate that most projects (1) addressed fewer than half of the basic criteria established for translocations and (2) were either unjustifiable from a conservation perspective or inadequately designed to guarantee success or preclude negative consequences. We propose a hierarchical decision-making system – an explicit method that integrates existing guidelines, thereby covering a key gap in conservation science – to reduce ambiguity when deciding whether to implement a given translocation project. This method will improve the likelihood of success in translocation projects and contribute to the efficient use of the limited resources available for these conservation efforts.

Front Ecol Environ 2012; 10(9): 494–501, doi:10.1890/110175 (published online 16 Oct 2012)

Species translocations (IUCN 1987) are increasingly used as key tools to offset the current biodiversity crisis caused by human impacts on populations and ecosystems (Panel 1; Figure 1; Griffith *et al*. 1989; Wolf *et al*. 1996; Fischer and Lindenmayer 2000; Sutherland *et al*. 2010). Although the potential of translocations to promote conservation seems straightforward, there are several reasons why implementing some projects, including assisted colonizations (Ricciardi and Simberloff 2009; Lawler and Olden 2011; Carrete and Tella 2012), is still vigorously debated. First, translocations have often been used haphazardly as a techno-fix for solving complex conservation problems without first considering the root causes of population declines (Frazer 1992; Meffe 1992). Second, an unknown proportion of projects appear to be conducted for philosophical, aesthetic, or sociopolitical reasons rather than for restoring the long-term viability of target populations (Sarrazin and Barbault 1996; Pons and Quintana 2003). Third, translocations are often unsuccessful, despite research efforts analyzing which factors will likely determine project success (Griffith *et al*. 1989, 1990; Wolf *et al*. 1998; Fischer and Lindenmayer 2000). Finally, translocation projects may be harmful in the long term as a result of unexpected associated impacts. Disease incidence, reduced population fitness caused by decreases in genetic diversity (inbreeding depression), the introduction of maladaptive alleles (outbreeding depression) in managed populations, or other unintended impacts on recipient communities may necessitate continual management of translocated populations and the supporting ecosystem, which is counterintuitive to the initial goal of restoring viable populations (Templeton 1990; Cunningham 1996; Storfer 1999; Ricciardi and Simberloff 2009).

In a nutshell:

- Translocation projects are increasingly used in attempts to reduce extinction risk, but it remains unclear which projects are necessary and which are likely to succeed
- We found that most translocation projects do not fully address criteria developed to ensure their utility
- We propose a system to evaluate the suitability of translocation projects by hierarchically assessing their necessity, associated risks, and technical and logistical design
- Application of this system by planners and wildlife managers would help in curbing species extinctions by reducing the number of inappropriate translocation projects and enabling more efficient use of scarce conservation resources

Existing guidelines for translocations (Table 1; WebPanel 1) indicate relevant issues to be considered before implementing such projects. Ideally, all translocations are expected to address these guidelines. However, according to the best available evidence, such guidelines cannot be used to decide when translocations should be undertaken because (1) scientists lack unambiguous criteria to judge whether a given project is suitable and likely to succeed and (2) guidelines do not consider differences in the relative importance of issues related to necessity and potential usefulness. For instance, resolving technical issues in the emerging field of reintroduction biology (Armstrong and Seddon 2008) would be irrelevant if translocations focused on species with adequate population sizes but that were otherwise threatened by overexploitation, habitat loss, invasive species, or loss of

[1]*Center for the Study of Institutional Diversity, Arizona State University, Tempe, AZ* [*]*(iperezib@asu.edu);* [2]*Departamento de Biología Aplicada, Ecología, Universidad Miguel Hernández, Elche, Alicante, Spain;* [3]*Department of Conservation Biology, Estación Biológica de Doñana (EBD-CSIC), Sevilla, Spain;* [4]*Department of Ecological Modeling, UFZ–Helmholtz Centre for Environmental Research, Leipzig, Germany;* [5]*Department of Biogeography and Global Change (BGC-MNCN), Museo Nacional de Ciencias Naturales (CSIC), Madrid, Spain;* [6]*Department of Environmental Sciences, Universidad de Castilla-La Mancha, Toledo, Spain*

USFWS

H Garrido/EBD-CSIC

Figure 1. *Translocations are an important tool for reducing the risk of extinction of threatened species, such as (a) the California condor (*Gymnogyps californianus*) in the US and (b) the Iberian lynx (*Lynx pardinus*) in Spain. However, translocations are also hotly debated because their success and usefulness are often doubtful.*

key mutualists (Caughley 1994). Criteria used to assess translocations should consider the main goal of each project and determine how issues related to this goal are hierarchically arranged throughout project development.

Here, we assess how recent and current translocations (including reintroductions, restocking, and assisted colonizations) address criteria designed to evaluate their necessity and potential usefulness. We first reviewed existing guidelines for translocations (WebPanel 1) and reformulated their recommendations into 10 main criteria (Table 1). Then, using two independent databases, we assessed whether ongoing translocations addressed these criteria. One database consisted of 280 studies published between 1996 and 2010 in eight major conservation biology journals (WebPanel 2), while the other database included 174 translocation projects developed for terrestrial vertebrates in Spain during the last two decades (WebPanel 3) – the latter database was chosen so as to avoid the potential effects of publication bias toward well-developed and successful projects, popular target taxa, or prominent scientific topics (Reading *et al.* 1997; Fischer and Lindenmayer 2000; Seddon *et al.* 2005; Bajomi *et al.* 2010). Spain was selected because of its high biodiversity and extensive history with nature conservation, including ex situ conservation programs (Morillo and Gómez-Campo 2000). Thorough consultation with scientists and conservation managers ensured that the Spanish database was complete, thus avoiding bias against unsuccessful projects. Compliance with criteria was assessed by selected experts through questionnaires (WebPanel 4).

Panel 1. Definition of terms

Translocation: the intentional release of organisms from one area into another, in an attempt to establish or re-establish viable, free-ranging populations of imperiled species (IUCN 1998). In general, the term translocation covers three types (IUCN 1987):

Introduction: the release by human agency of an organism outside its historically known native range. A particular type of introduction is known as assisted colonization or assisted migration (ie the translocation of species to previously unoccupied ranges predicted to be favorable for persistence under future climate scenarios); in some cases, however, assisted colonization may constitute a reintroduction (see below).

Reintroduction: the release of an organism into a part of its native range from which it has disappeared or become extirpated in historical times.

Restocking: the release of organisms to enhance the number of individuals of that species in an original habitat.

Criteria for evaluating translocation projects

A review of existing guidelines (rightmost column in Table 1) generated several recommendations (WebTable 1), which we sorted according to the following 10 main criteria, to improve translocation practices:

(1) Is the species or population under threat?

The first step is to assess the extent to which the target species or population is threatened, as well as to determine its conservation status (IUCN 1987, 1998), which must be evaluated within metapopulation and regional contexts (Palsboll *et al.* 2007).

(2) Have the threatening factors been removed or controlled, or were they absent in the release area?

Prior to translocation, it is essential to analyze the factors that threaten the target species or population. A translocation is not advisable if threatening factors are sustained or uncontrolled in the release area (IUCN 1987, 1998; Kleiman 1989; Kleiman *et al.* 1994).

(3) Are translocations the best tool to mitigate conservation conflicts?

Before translocation is undertaken, the best available management options must be selected to eliminate threats and to assess the reason for population decline (IUCN 1987; Griffith *et al.* 1989; Kleiman 1989; Kleiman *et al.* 1994). If the species or population is not at risk because of small population size but is instead declining as a result of direct or indirect human impacts, solving or compensating such impacts by in situ conservation actions could be a better alternative (Caughley 1994).

(4) Are risks for the target species acceptable?

Translocations are also unadvisable if they may threaten either the source or recipient populations (Kleiman 1989; Kleiman *et al.* 1994; IUCN 1998; Carrete and Tella 2012). For example, translocations can promote disease spread, genetic mixing, and change in social structure or behavior, among other outcomes (IUCN 1987, 1998; Griffith *et al.* 1989; Cunningham 1996). The possibility of contemporary evolution (Pelletier *et al.* 2009), as well as behavioral and physiological changes in captive populations (Archard and Braithwaite 2010; Mason 2010), should also be considered when evaluating source populations.

(5) Are risks for other species or the ecosystem acceptable?

Translocations may impact other species (Williams *et al.* 1988; Stanley-Price 1991; Cunningham 1996) or the source or recipient ecosystem (Cunningham 1996; IUCN 1998). This is especially relevant for keystone species such as top predators, for release sites when target species have long been extirpated (Rees 2001), and for assisted colonizations where translocated species may become invasive (Ricciardi and Simberloff 2009).

(6) Are the possible effects of the translocation acceptable to local people?

An analysis of potential conflicts and risks to the socioeconomic system of release sites must be carried out (Stanley-Price 1991; Kleiman *et al.* 1994; IUCN 1998). The attitudes of people who might be affected by the translocation should be investigated and, if necessary, modified in an effort to improve local acceptance (IUCN 1987, 1998; Reading *et al.* 1991; Stanley-

Table 1. Existing criteria for translocations

Level	*Criteria*	*Guidelines*
1st Necessity of the translocation	(1) Is the species or population under threat?	IUCN (1987, 1998)
	(2) Have the threatening factors been removed or controlled, or were they absent in the release area?	IUCN (1987, 1998); Kleiman (1989); Dodd and Seigel (1991); Kleiman *et al.* (1994); Miller *et al.* (1999)
	(3) Are translocations the best tool to mitigate conservation conflicts?	IUCN (1987, 1998); Kleiman (1989); Kleiman *et al.* (1994)
2nd Risk evaluation	(4) Are risks for the target species acceptable?	IUCN (1987, 1998); Williams *et al.* (1988); Kleiman (1989); Dodd and Seigel (1991); Stanley-Price (1991); Kleiman *et al.* (1994); Cunningham *et al.* (1996); Miller *et al.* (1999)
	(5) Are risks for other species or the ecosystem acceptable?	Williams *et al.* (1988); Stanley-Price (1991); Cunningham *et al.* (1996); IUCN (1998)
	(6) Are the possible effects of the translocation acceptable to local people?	IUCN (1987, 1998); Reading *et al.* (1991); Stanley-Price (1991); Kleiman *et al.* (1994)
3rd Technical and logistical suitability	(7) Does the project maximize the likelihood of establishing a viable population?	IUCN (1987, 1998); Williams *et al.* (1988); Griffith *et al.* (1989); Kleiman (1989); Dodd and Seigel (1991); Reading *et al.* (1991); Stanley-Price (1991); Short *et al.* (1992); Kleiman *et al.* (1994); Cunningham *et al.* (1996); Wolf *et al.* (1996); Miller *et al.* (1999)
	(8) Does the project include clear goals and monitoring?	IUCN (1987, 1998); Williams *et al.* (1988); Kleiman (1989); Dodd and Seigel (1991); Short *et al.* (1992); Cunningham *et al.* (1996); Miller *et al.* (1999)
	(9) Do enough economic and human resources exist?	IUCN (1987, 1998); Kleiman (1989); Reading *et al.* (1991); Stanley-Price (1991); Kleiman *et al.* (1994); Miller *et al.* (1999)
	(10) Do scientific, governmental, and stakeholder groups support the translocation?	Kleiman (1989); Reading *et al.* (1991); Kleiman *et al.* (1994); IUCN (1998)

Notes: Criteria are grouped into three levels within the Hierarchical Decision-making System for Translocations; these are obtained from recommendations and guidelines pertaining to translocations (see also WebPanel 1).

Price 1991). Translocations are unadvisable if target species could jeopardize human lives or diminish quality of life, or if human behavior could substantially affect the survival of the released individuals (Stanley-Price 1991; Kleiman *et al.* 1994; IUCN 1998).

(7) Does the project maximize the likelihood of establishing a viable population?

All factors that might affect the survival of the released individuals and the establishment of a viable population should be taken into account. Several aspects – including release site selection, the number and composition of individuals to be released, and the methodology used – should be considered before release at the new site (Williams *et al.* 1988; Griffith *et al.* 1989; Kleiman *et al.* 1994; Wolf *et al.* 1996). During the development phase, efforts should be focused on ensuring that animals can easily adapt to their new surroundings (IUCN 1987, 1998; Kleiman 1989; Reading *et al.* 1991).

(8) Does the project include clear goals and monitoring?

Translocation should include long-term monitoring to assess progress toward explicit objectives (Williams *et al.* 1988; Kleiman 1989; Dodd and Seigel 1991). An adaptive management approach should be pursued to provide evidence for cause–effect relationships and to find optimal strategies that will improve results (IUCN 1987, 1998; Short *et al.* 1992; Miller *et al.* 1999), which should be made readily available to scientists and managers (IUCN 1987, 1998; Williams *et al.* 1988; Miller *et al.* 1999).

(9) Do enough economic and human resources exist?

During all phases of a translocation project, sufficient economic resources (IUCN 1987; Kleiman 1989; Stanley-Price 1991; Kleiman *et al.* 1994) and trained staff (Reading *et al.* 1991; IUCN 1998; Miller *et al.* 1999) must be available. Detailed estimates of expenses for the duration of the project, including post-release monitoring, are key to evaluating whether a given project meets this criterion (Karesh 1993).

(10) Do scientific, governmental, and stakeholder groups support the translocation?

Participation by and interaction between the different stakeholders interested in, associated with, or affected by the translocation (eg local government, non-governmental organizations, the scientific community) are vital to ensure successful project management. To help achieve this, we argue that, among other things, all pertinent laws, treatises, and agreements – at international, national, state, and local levels – should be respected. An investment in environmental education is also highly recommended (Kleiman 1989; Reading *et al.* 1991; Kleiman *et al.* 1994; IUCN 1998).

Compliance with criteria

Most of the examined projects, either published or unpublished, did not fully address the 10 main criteria (Figure 2b). In the absence of an unambiguous decision-making system, translocation projects will likely fail to meet conservation goals. To counteract this, we propose a decision-making system by arranging the 10 criteria according to an explicit goal – namely, restoring the long-term viability of wild populations of the species being translocated.

Published translocation projects

Most of the published studies (80%) focused on technical aspects (ie *criterion 7* – mechanisms to improve and increase the efficiency of translocation projects, to maximize their success; Figure 2a). Fifty-three percent of the studies included a long-term monitoring program or considered the importance of monitoring (*criterion 8*). Although these factors are necessary for successful translocations and to improve translocation techniques, other important aspects – such as evaluation of adverse consequences of translocations for the target species (*criterion 4*) or for other species or the ecosystem (*criterion 5*) – are barely represented in the scientific literature (26% and 7%, respectively). Although 63% of the studies involved threatened species (*criterion 1*), only 20% of the studies acknowledged the cause of declines (*criterion 2*), and 56% of the studies failed to justify the need for the project (*criterion 3*). Resources and organizational issues of translocations (*criteria 9* and *10*) were rarely represented (11% and 9%, respectively). None of the studies reviewed or mentioned all 10 criteria (median = three criteria; Figure 2b). However, some criteria may have been addressed by the translocation projects but were not mentioned in the scientific literature.

Unpublished translocation projects

According to experts, 36% of unpublished translocations in Spain were considered not to be the best option for conservation of the species (*criterion 3*; Figure 2a). The specific threat status of the targeted population was unknown in 44% of projects (*criterion 1*), and target species were listed as either Not Threatened or Least Concern (IUCN 2010) in 55% of projects (WebTable 3). The causes of species or population declines were unknown in 41% of the projects (*criterion 2*). Experts maintained that there were or could be adverse consequences for the target species (*criterion 4*) or for other species or the ecosystem (*criterion 5*) in 57%

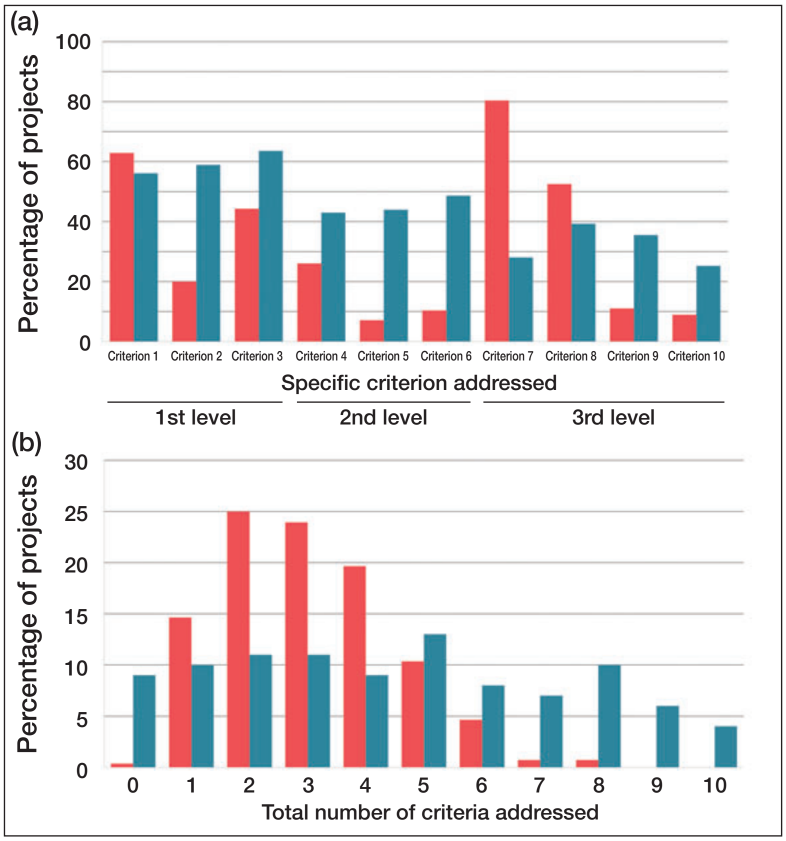

Figure 2. *Percentage of published projects worldwide (red) as well as published and unpublished projects in Spain (blue) that addressed (a) each particular criterion for translocation and (b) between 0 and 10 of the criteria altogether.*

and 56% of the projects, respectively. Almost half (49%) of the projects made allowances for possible conflicts with local human populations (*criterion* 6). Seventy-two percent of the projects neglected to consider all of the aspects that would be important for establishing a viable population (*criterion 7*), and less than half (39%) included adequate monitoring (*criterion* 8). Finally, many of the projects possessed insufficient human and economic resources (64%; *criterion* 9) and did not address the necessary implications of key stakeholder groups (75%; *criterion 10*). Only four projects (4%) fully complied with translocation criteria, whereas 10 projects (9%) did not address any (median = five criteria; Figure 2b).

Comparison between published and unpublished projects

We found a wide disparity between criteria (with the exception of *criterion 1*) achieved through both published and unpublished translocation studies (Wilcoxon test, $P < 0.001$). A greater proportion of unpublished projects addressed seven of the 10 criteria, as compared with published projects (Figure 2a). However, the technical and monitoring aspects of translocations (*criteria 7* and 8) were more frequently represented in published than in unpublished translocations; this might also indicate that translocations with long-term monitoring plans in place are more frequently published (Fischer and Lindenmayer 2000). Technical aspects are currently promoted within the discipline of reintroduction biology as a way to improve reintroduction outcomes (Seddon *et al.* 2007), yet more than half of the unpublished projects failed to meet these criteria.

The representation of *criteria 2* and *3* (ie that causes of population declines are controlled and translocations are the best tool to mitigate conflict) was higher in unpublished than in published projects. We would expect the opposite result, given that well-executed translocations and studies of endangered species are more likely to be published (Fischer and Lindenmayer 2000; Seddon *et al.* 2005; Bajomi *et al.* 2010). However, the issues analyzed in *criteria 2* and *3* are probably more easily found in gray literature sources, and 3.5% of papers focused on translocations of non-threatened species. In addition, despite that most Spanish translocations did not fully address the criteria listed above, Spain may represent a good example of how translocations are developed. Indeed, a higher percentage of criteria was met by Spanish translocations than by projects around the world (Wilcoxon test, $P < 0.001$; Figure 2b).

Issues related to resources and support by stakeholder groups (*criteria* 9 and *10*) were more frequently represented in unpublished projects. Reading *et al.* (1997) also noticed that valuation and organizational issues related to translocations were rarely discussed in the scientific literature. Translocation risks (*criteria 4–6*) were also less frequently assessed in the scientific literature and were included in fewer than half of Spanish translocations examined. This is an important deficiency. Assessing the impacts of released species on ecosystems was highlighted by Armstrong and Seddon (2008) as a key question for reintroduction biology and constitutes one of the major concerns regarding assisted colonizations (Ricciardi and Simberloff 2009). Other studies have noted that human dimensions (eg human attitudes toward translocations) are underrepresented in published translocation studies (Seddon *et al.* 2007) and in translocations in general (Reading *et al.* 1991).

Hierarchical Decision-making System for Translocations

Full compliance with the 10 criteria will imply that translocation projects are justifiable in terms of conservation and that issues that could compromise project success have been considered, based on the best available evidence. However, partial compliance cannot be used to determine whether a certain project may be valuable for conserving target species. As a solution, we propose a hierarchical assessment of criteria, which (1) is justified

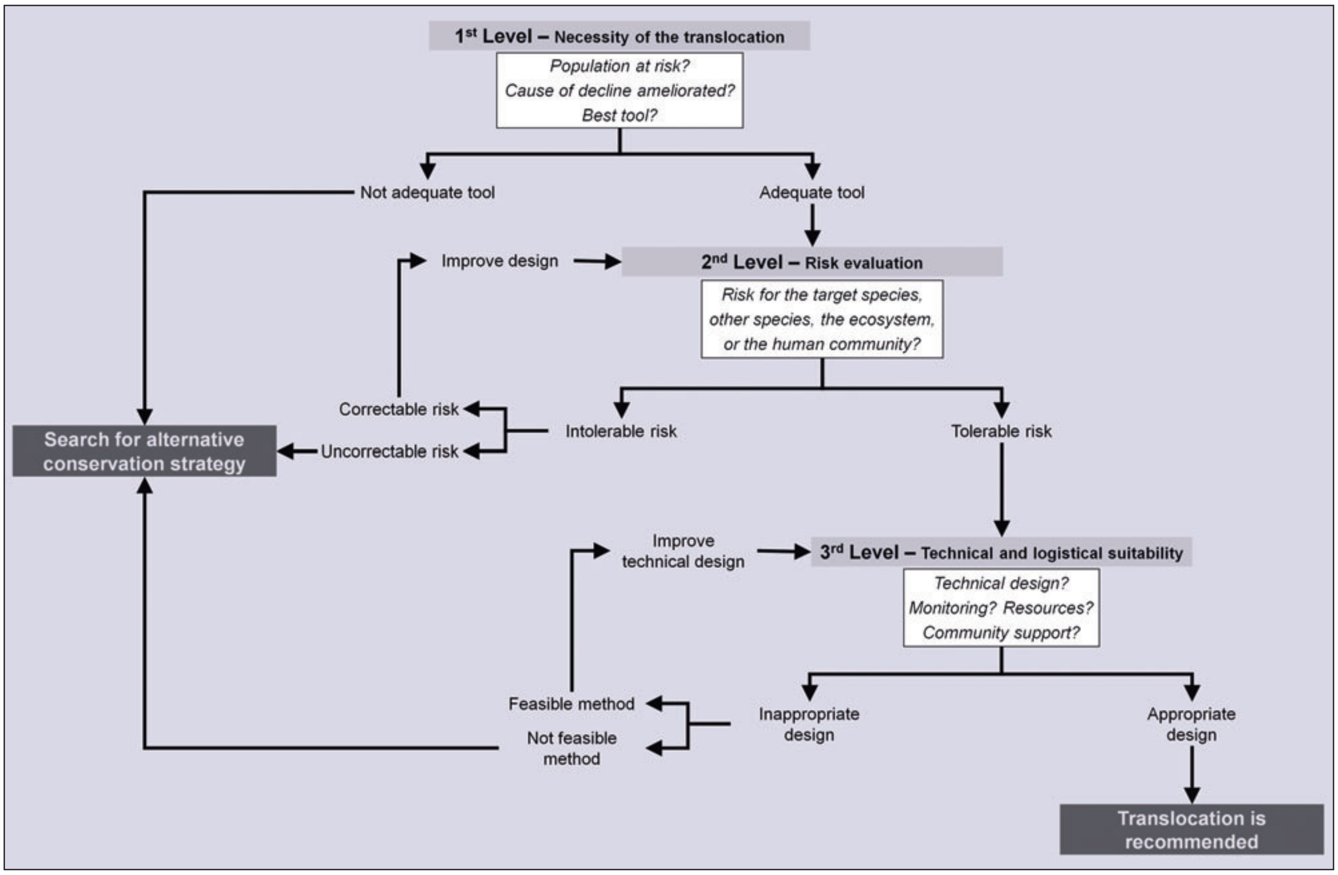

Figure 3. *Hierarchical Decision-making System for Translocations. The first step is to evaluate whether translocating individuals is necessary for the conservation of a threatened species or population (1st level). Subsequently, the inherent risks involved are assessed (2nd level) and the methodological design of the translocation is evaluated (3rd level) (see also Table 1). The negative evaluation of the first level indicates that the project should not be carried out and alternative conservation strategies should be found. Conversely, a negative evaluation of the second and third levels may be overcome if the translocation's design is improved.*

because some criteria during decision making are subordinate to others and (2) helps to avoid subjectivity at the final stage of decision making.

Our Hierarchical Decision-making System for Translocations (HDST) nests the 10 criteria for translocations into successive decision levels (Table 1). Rather than proposing new criteria, we integrated recommendations from current guidelines (WebTable 1) to obtain a step-by-step methodology for evaluating translocations in a conservation context. We grouped the 10 criteria within the HDST into three levels, considering: (1) importance in the decision-making process, (2) adverse consequences if not fulfilled, and (3) options in case of a negative evaluation.

The first level, "*Necessity of the translocation*" (*criteria 1–3*), assesses whether the project will be carried out with adequate conservation objectives and whether translocation is the most adequate tool for conserving the threatened species or population. The second level, "*Risk evaluation*" (*criteria 4–6*), aims to ensure that impacts will be mitigated. The third level, "*Technical and logistical suitability*" (*criteria 7–10*), attempts to maximize the likelihood of success in terms of establishing new viable populations.

Each criterion within the three levels should be evaluated successively (Figure 3). If a translocation proceeds without fulfilling the first level, the project would not be of much value to the intended species and could even have a negative effect if resources are spent on the translocation project instead of on more appropriate actions. If a translocation proceeds without fulfilling the second level, the project could have unintended or negative effects on other elements of the ecosystem. If a translocation proceeds without fulfilling the third level, the project could fail; in this case, however, there would be no direct negative consequences for conservation, apart from the waste of economic resources.

We acknowledge that several translocation projects may omit some criteria on the basis that doing so would not compromise project viability. For example, (1) translocations with aims other than conservation (eg restocking of exploited species or engaging in pest control, not considered in this review) do not need to fulfill criteria in the first level; (2) well-known and risk-free translocation projects may omit the necessity of long-term monitoring; and (3) specifically for assisted colonizations, once the action has been considered necessary to protect the species from climate change, the first level is considered to be fulfilled. However, other projects

could have ambiguous goals that might negatively affect their feasibility and usefulness as conservation tools. For this reason, we strongly recommend that translocation projects with a conservation goal should fully comply with the proposed decision-making system.

The next step in applying the HDST is to select the most appropriate methods to assess compliance of criteria. For example, population models and population viability analysis should be used when assessing the suitability of the translocation (*criterion 3*). Expert opinion may be used in evaluating risk (*criteria 4*–*6*) or for determining threats to species or populations (*criteria 1* and *2*), although quantitative methods are strongly recommended if available.

Compliance with the HDST

According to the proposed system, of the Spanish translocations evaluated, 65% were unnecessary (1st level), 79% might have negative risks (2nd level), and 90% were not technically well designed (3rd level). Of those projects considered necessary, only 30% could guarantee that no major risks existed, and only 36% of the projects that fulfill the first and second levels had an adequate technical and logistical design. Thus, according to our proposed methodology, only 4 projects (4% of those currently underway) are recommended and adequately designed for conserving the target species.

Potential biases precluded a robust examination of how well published projects correlate with the HDST. However, a comparison between projects around the world with the unpublished Spanish projects is likely to show similarities (see also Figure 2).

Conclusions

Despite the conservation potential of translocations, the majority of projects reviewed here did not fulfill all the necessary criteria. Most projects were difficult to justify in terms of conservation or were not designed well enough to avoid negative consequences. We suggest that the use of the HDST by conservation planners and managers could improve the effectiveness of translocations and promote the efficient use of scarce monetary resources.

Scholarly journals could contribute to this goal by encouraging authors writing about translocation projects to submit their work for consideration and to explicitly justify the need for the projects. Results of translocation projects involving non-threatened species, although important in developing the discipline of reintroduction biology (Seddon *et al.* 2007), may not be applicable to translocations of endangered species (Fischer and Lindenmayer 2000; Caro 2005). Moreover, non-threatened species translocations should not be presented as "conservation" projects but should comply with risk assessment criteria. We recommend that the risks and human dimensions of translocations, both of which are underrepresented in published and unpublished projects, should be carefully addressed during project design. Assessment of techniques to improve translocation success should also continue (Armstrong and Seddon 2007; Sutherland *et al.* 2010).

Acknowledgements

We thank all of the experts involved in evaluating translocation projects in Spain. IP was partially funded by Fundación Séneca (Murcia, Spain). J Senko and J Ramos reviewed the English text.

References

Archard GA and Braithwaite VA. 2010. The importance of wild populations in studies of animal temperament. *J Zool* **281**: 1–12.

Armstrong DP and Seddon PJ. 2008. Directions in reintroduction biology. *Trends Ecol Evol* **23**: 20–25.

Bajomi B, Pullin AS, Stewart GB, *et al.* 2010. Bias and dispersal in the animal reintroduction literature. *Oryx* **44**: 358–65.

Caro T. 2005. Use of substitute species in conservation biology. *Conserv Biol* **19**: 1821–26.

Carrete M and Tella JL. 2012. Is assisted colonization feasible? Lessons from past introductions. *Front Ecol Environ* **10**: 12–13.

Caughley G. 1994. Directions in conservation biology. *J Anim Ecol* **63**: 215–44.

Cunningham AA. 1996. Disease risks of wildlife translocations. *Conserv Biol* **10**: 349–53.

Dodd CK and Seigel RA. 1991. Relocation, repatriation, and translocation of amphibians and reptiles: are they conservation strategies that work? *Herpetologica* **47**: 336–50.

Fischer J and Lindenmayer DB. 2000. An assessment of the published results of animal relocations. *Biol Conserv* **96**: 1–11.

Frazer NB. 1992. Sea turtle conservation and halfway technology. *Conserv Biol* **6**: 179–84.

Griffith B, Scott JM, Carpenter JW, *et al.* 1989. Translocation as a species conservation tool: status and strategy. *Science* **245**: 477–80.

Griffith B, Scott JM, Carpenter JW, *et al.* 1990. Translocations of captive-reared terrestrial vertebrates 1973–1986. *Endangered Species Update* **8**: 10–14.

IUCN (International Union for Conservation of Nature). 1987. IUCN position statement on translocation of living organisms: introductions, reintroductions and re-stocking. Gland, Switzerland: IUCN.

IUCN (International Union for Conservation of Nature). 1998. IUCN guidelines for re-introductions. Gland, Switzerland, and Cambridge, UK: IUCN.

IUCN (International Union for Conservation of Nature). 2010. IUCN Red List of threatened species. Version 2010.4. www.iucnredlist.org. Viewed 9 Nov 2010.

Karesh WB. 1993. Cost evaluation of infectious disease monitoring and screening programs for wildlife translocation and reintroduction. *J Zoo Wildlife Med* **24**: 291–95.

Kleiman DG. 1989. Reintroductions of captive mammals for conservation: guidelines for reintroduced endangered species into the wild. *BioScience* **39**: 152–61.

Kleiman DG, Price MRS, and Beck BB. 1994. Criteria for reintroductions. In: Olney PJS, Mace GM, and Feistner ATC (Eds). Creative conservation: interactive management of wild and captive animals. London, UK: Chapman & Hall.

Lawler JJ and Olden JD. 2011. Reframing the debate over assisted colonization. *Front Ecol Environ* **9**: 569–74.

Mason GJ. 2010. Species differences in responses to captivity: stress, welfare and the comparative method. *Trends Ecol Evol* **25**: 713–21.

Meffe GK. 1992. Techno-arrogance and halfway technologies: salmon hatcheries on the Pacific coast of North America. *Conserv Biol* **6**: 350–54.
Miller B, Ralls K, Reading RP, *et al.* 1999. Biological and technical considerations of carnivore translocation: a review. *Anim Conserv* **2**: 59–68.
Morillo C and Gómez-Campo C. 2000. Conservation in Spain, 1980–2000. *Biol Conserv* **95**: 165–74.
Palsboll PJ, Berube M, and Allendorf FW. 2007. Identification of management units using population genetic data. *Trends Ecol Evol* **22**: 11–16.
Pelletier F, Reále D, Watters J, *et al.* 2009. Value of captive populations for quantitative genetics research. *Trends Ecol Evol* **24**: 263–70.
Pons P and Quintana XD. 2003. Unsuitable reintroductions and conservation priorities. *Oryx* **37**: 285.
Reading RP, Clark TW, and Griffith B. 1997. The influence of valuational and organizational considerations on the success of rare species translocations. *Biol Conserv* **79**: 217–25.
Reading RP, Clark TW, and Kellert SR. 1991. Towards an endangered species reintroduction paradigm. *Endangered Species Update* **8**: 1–4.
Rees PA. 2001. Is there a legal obligation to reintroduce animal species into their former habitats? *Oryx* **35**: 216–23.
Ricciardi A and Simberloff D. 2009. Assisted colonization is not a viable conservation strategy. *Trends Ecol Evol* **24**: 248–53.
Sarrazin F and Barbault R. 1996. Reintroduction: challenges and lessons for basic ecology. *Trends Ecol Evol* **11**: 474–78.
Seddon PJ, Soorae PS, and Launay F. 2005. Taxonomic bias in reintroduction projects. *Anim Conserv* **8**: 51–58.
Seddon PJ, Armstrong DP, and Maloney RF. 2007. Developing the science of reintroduction biology. *Conserv Biol* **21**: 303–12.
Short J, Bradshaw SD, Giles J, *et al.* 1992. Reintroduction of macropods (Marsupialia: Macropodoidea) in Australia – a review. *Biol Conserv* **62**: 189–204.
Stanley-Price MR. 1991. Animal re-introductions: the Arabian oryx in Oman. Cambridge, UK: Cambridge University Press.
Storfer A. 1999. Gene flow and endangered species translocations: a topic revisited. *Biol Conserv* **87**: 173–80.
Sutherland WJ, Armstrong D, Butchart SHM, *et al.* 2010. Standards for documenting and monitoring bird reintroduction projects. *Conserv Lett* **3**: 229–35.
Templeton AR. 1990. The role of genetics in captive breeding and reintroduction for species conservation. *Endangered Species Update* **8**: 14–17.
Williams JE, Sada DW, and Williams CD. 1988. American Fisheries Society guidelines for introductions of threatened and endangered fishes. *Fisheries* **13**: 5–11.
Wolf CM, Garland T, and Griffith B. 1998. Predictors of avian and mammalian translocation success: reanalysis with phylogenetically independent contrasts. *Biol Conserv* **86**: 243–55.
Wolf CM, Griffith B, Reed C, *et al.* 1996. Avian and mammalian translocations: update and reanalysis of 1987 survey data. *Conserv Biol* **10**: 1142–54.